Identification of water signature at gully exposed sites on Mars by Hyperspectral image analysis.

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Abstract

Formation mechanism of gullies in the crater walls of Mars has been a debate throughout. Many hypotheses have been proposed for the formation mechanism of gullies in crater walls. But nothing has convincingly proved. In their work Fan et. al (2008) selected four gully exposed sites in Mars to identify water signature using OMEGA data. There work had limitations in terms of special resolution of OMEGA data, and strong carbon dioxide absorption around 2μm. In this work an attempt has been made to identify water signature in gully exposed sites of Mars using CISM data in one of the gully exposed sites of the study area of Fan et. al (2008). Atmospheric correction has been done for the CRISM dataset to minimize the carbon dioxide absorption noise. With fine resolution of CRISM data that is 17 meter feeble water absorption depth has been identified in gully exposed site of the study area.

Introduction

High-resolution images from the Mars Obiter Camera (MOC) onboard the Mars Global Surveyor (MGS) show different gully features on sloped surfaces of Mars. The mechanism of gully formation is still under debate. Majority of studies tend to favor a mechanism related to liquid water flow based on geomorphology and fluid mechanics considerations for formation of gully in Mars (Parker et al., 1989; Malin and Edgett, 2000a, 2003; Fairén, et al., 2003; Mangold et al., 2004; Solomon et al., 2005). Malin and Edgett (2000a) first described gullies imaged by the Mars Obiter Camera (MOC) (1.5 to 12.0 m/pixel) aboard the Mars Global Surveyor (MGS). The gully features have been found on crater walls, valley walls, polar pits, scarp faces, mesas, and fretted terrain mostly in areas of 30º – 72 º latitude in both hemispheres (Heldmann and Mellon, 2004). Fan et. al (2008) examined four gully exposed sites by means of Visible and Infrared Mineralogical Mapping Spectrometer (OMEGA) imagery to identify the physical processes involved in formations of those gullies. Investigation of the four sites in their study showed greater absorption depths of water-related bands at the gully-exposed sites than those at the adjacent pixel ring, and smaller absorption depths of water-related bands in the surrounding pixel rings which indicates water is one of the physical agents behind formation of those gullies. But there work has limitations in terms of following;

1. Limited knowledge of grain size that might have affected the absorption depth;
2. The influence of seasonal temperature changes on imaged materials;
3. Strong CO_2 absorption features at wavelengths around 2 μm both in the solid state and in the atmosphere (Langevin et al. 2007), especially for the gully-exposed site close to the polar areas;
4. The limitation of the spatial resolution of OMEGA hyperspectral images in the case study,
5. Errors in registering gully-exposed sites found from MOC images to OMEGA images due to the possible inaccuracy of two geo-referencing systems.

Therefore in their work Fan et. al (2008) could not able to make a convincing conclusion about the formation of gullies by means of water, depending only on the absorption depths of water related bands. In this work one of the gully exposed sites of the study area of Fan et al (2008) has been examined to identify water signature using CRISM data.

Data and method used

In this work CRISM data has been obtained from http://pds-geosciences.wustl.edu/missions/mro/crism.htm which is free download. Thermal long and short wave length bands are selected to make the composite image using IDL code. Spectral range is 0.4036 to 2.6153 µm. Location of gully exposed site is northeast wall of Hale Crater (35.5ºS/324.6ºE). Pixel resolution is 17 meter. Atmospheric correction was made using the model provided by the CRISM team. This model assumes that the Martian atmospheric column is homogeneous and the materials on the summit and at the base of Olympus Mons are identical. Atmospheric absorptions could be removed by dividing the reflectance spectra by a ratio of spectra acquired on Olympus Mons and scaled to the same column density of CO_2 (Langevin et al., 2005). Figure 1 is the composite hyperspectral image of the study area after atmospheric correction.

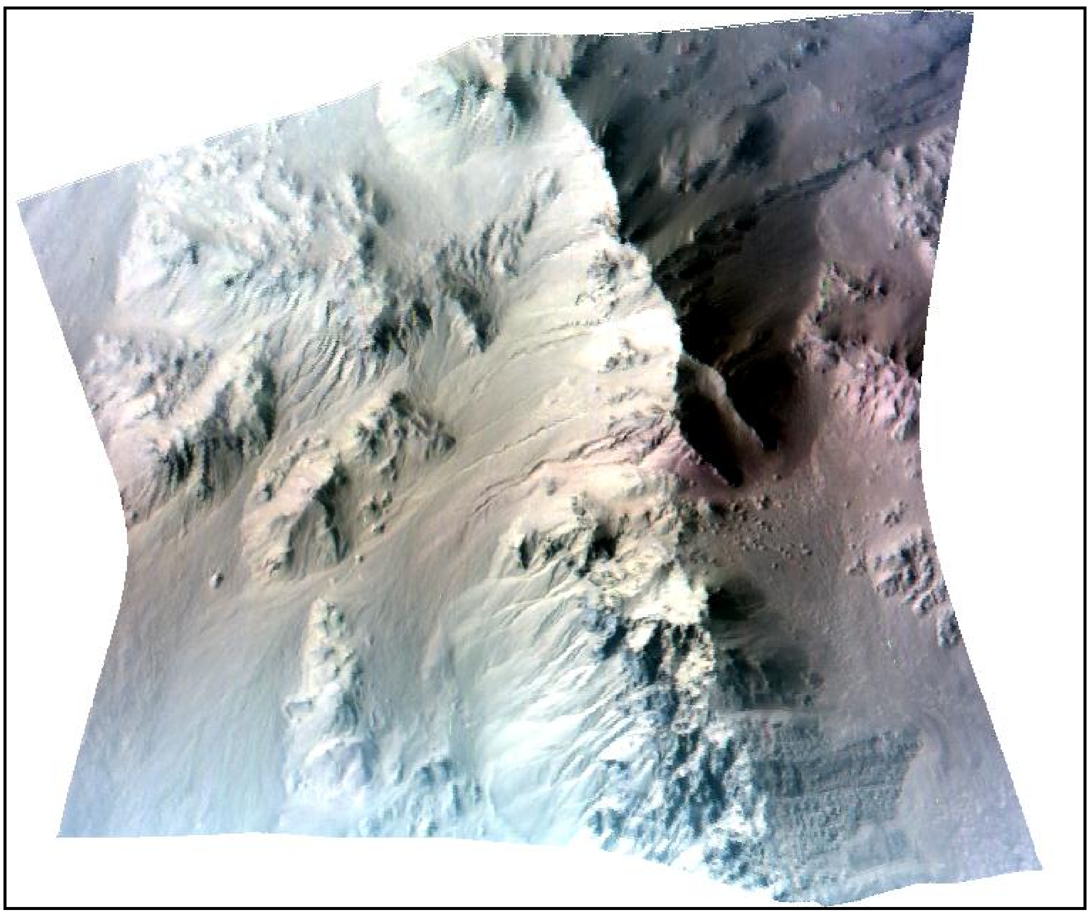

Figure 1: Hyperspectral image of the study area under investigation after atmospheric correction.

Four gully exposed sites and two non gully exposed site were selected to extract reflectance spectral signature to identify water absorption depth. Region of interest for extraction of spectral signature is shown in figure 2. After extraction of spectral signature a continuum was removed to analyze absorption features as described by Clark (1981a) and Clark and Roush (1984). The absorption depth is calculated using two adjacent spectral channels of continuum spectra. Spectral signature of the region of interest is shown in figure 3. To identify water absorption depth the wavelengths selected are as follows 1.04µm, 1.4 µm, 1.5 µm, 1.8 µm, 1.87 µm, 1.91 µm. The reason is isolated water molecules have absorption bands at 0.94 µm , 1.14 µm, 1.38 µm, 1.45 µm, and ~1.87 µm (Hunt and Salisbury, 1970). After getting the absorption depths of corresponding individual wavelengths, average of absorption depth has been taken for corresponding wavelengths of different location. Absorption depths are shown in Table 1 for gully exposed sites and non gully exposed sites.

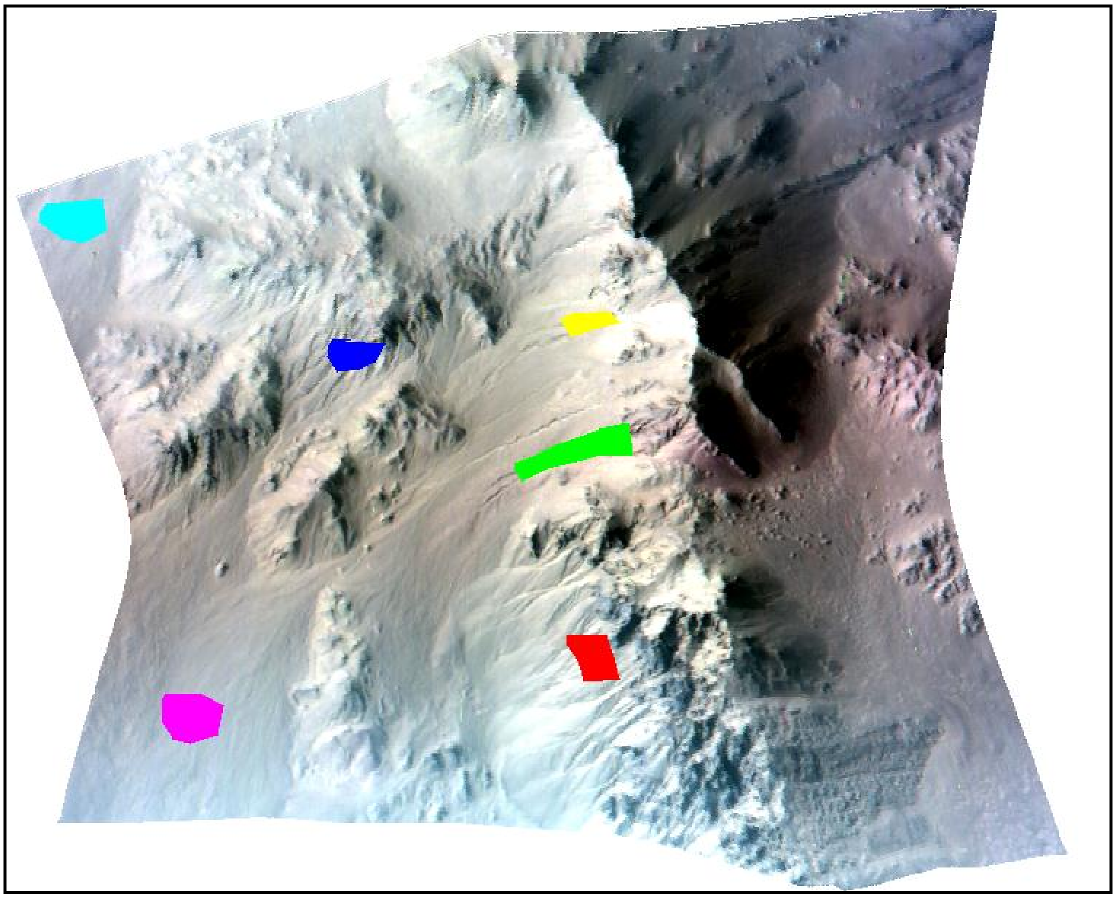

Figure 2: Region of interest marked by different colors to extract spectral signature to identify water absorption depth.

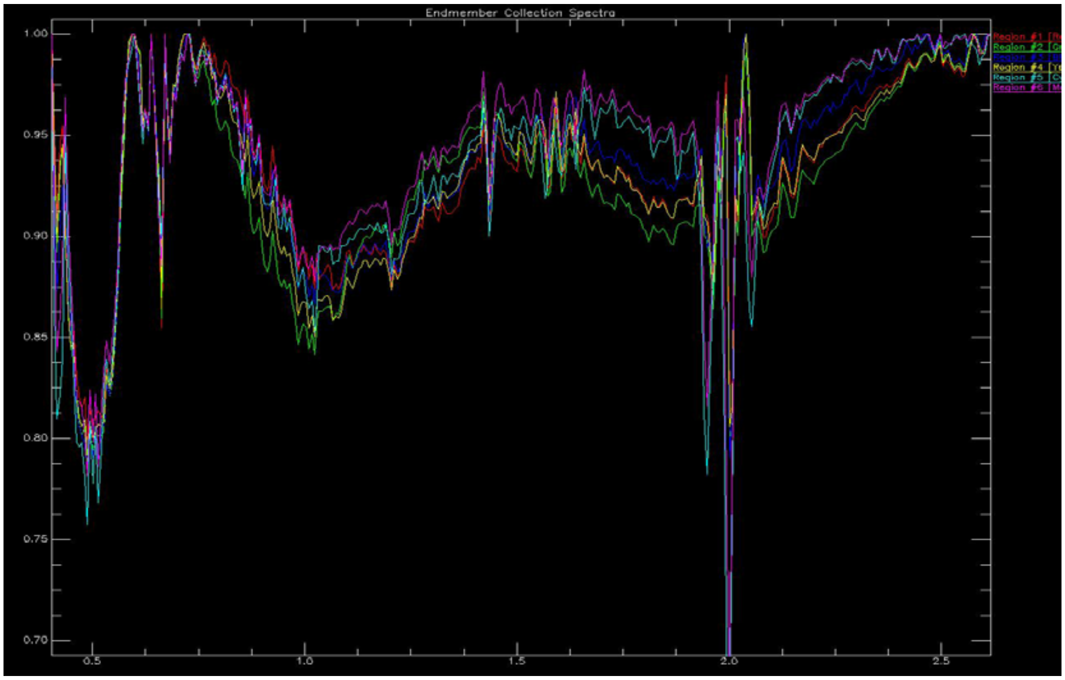

Figure 3: Spectral signature of the region of interest after continuum removed.

WAVE LENGTH	GULLY EXPOSED SITE					NO GULLY		
	LOCATION 1 (RED)	LOCATION 2 (GREEN)	LOCATION 3 (BLUE)	LOCATION 4 (YELLOW)	AVERAGE	LOCATION 1 (CYAN)	LOCATION 2 (MAGENTA)	AVERAGE
1.04	0.1138	0.1098	0.1108	0.1063	0.11018	0.1112	0.1093	0.11025
1.4	0.1206	0.1163	0.1218	0.112	0.11768	0.1156	0.1151	0.11535
1.5	0.1204	0.1159	0.12	0.1117	0.11700	0.1157	0.1145	0.11510
1.8	0.118	0.1139	0.1161	0.1088	0.11420	0.1138	0.1115	0.11265
1.87	0.118	0.113	0.1162	0.1083	0.11388	0.1104	0.1089	0.10965
1.91	0.1179	0.1138	0.1164	0.1085	0.11415	0.1124	0.1108	0.11160

Table 1: Absorption depths of corresponding wavelengths of different region of interest after continuum removal.

Results and discussion

All the region of interest shows water absorption depths corresponding to the wavelength chosen. For wavelength 1.04 µm water absorption depth of gully exposed site is lower than non gully exposed sites. But for other wavelengths average water absorption depth is slightly higher in gully exposed site than non gully exposed site. This supports the conclusion of Fan et al (2008) that there is water signature in gully exposed sites.

Future work

This work definitely supports that there is water signature in gully exposed sites. But the absorption depth is feeble for gully exposed site than non gully exposed site. To get strong water signature in gully exposed site other locations need to be examined.

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